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Evaluation and Demonstration of Non-Hexavalent Chromium Pretreatments and Sealers for Steel Substrates

ASETSDefense 2009

Westin Westminster

Westminster, Colorado 80020

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE SEP 2009		2. REPORT TYPE		3. DATES COVERED 00-00-2009 to 00-00-2009	
4. TITLE AND SUBTITLE Evaluation and Demonstration of Non-Hexavalent Chromium Pretreatments and Sealers for Steel Substrates				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U. S. Army Research Laboratory,BLDG 4600, Deer Creek Loop,Aberdeen Proving Ground,MD,21005				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES ASETSDefense 2009: Sustainable Surface Engineering for Aerospace and Defense Workshop, August 31 - September 3, 2009, Westminster, CO. Sponsored by SERDP/ESTCP.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 23	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

**DOD Corrosion
Project #W09AR02**
“Corrosion Mitigation for
High Strength Steel
Based Armor Systems
Through Improved
Inhibiting Pretreatments
and Processes

Project 09 E-WP4-019
Non-chromate, Zero-VOC
Coatings for Steel
Substrates on Army and
Navy Aircraft and Ground
Vehicles

DOD Corrosion
Sacrificial Coatings Used
in the Corrosion
Protection of Carbon and
Hardened Steels for
Tactical and Armored
Weapon

**Evaluation and Demonstration
of Non-Hexavalent Chromium
Pretreatments and Sealers for
Steel Substrates**



NAV AIR

**Implementation of Non-hex
Chrome Alternatives**

- Demonstrate and Validate performance of alternative pretreatments and sealers on Army and Navy systems
- Recommend for implementation proven alternatives at military and OEM facilities



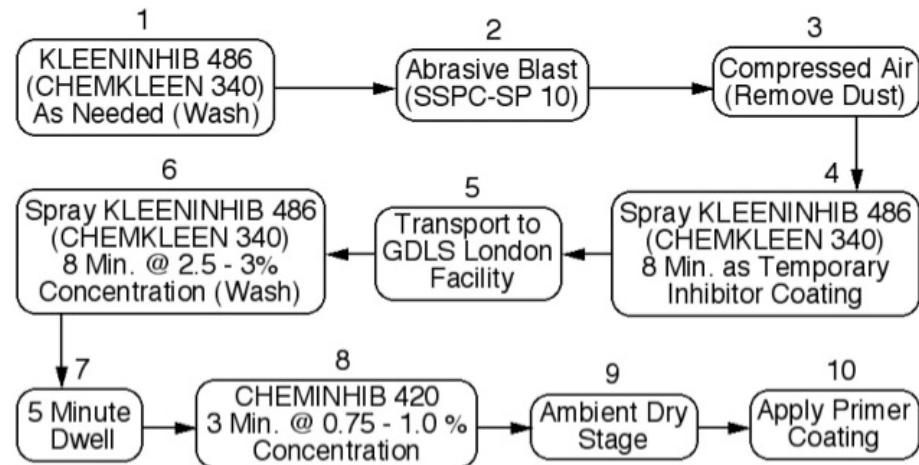
- Zinc and Manganese-phosphate with chromate rinse
- Sacrificial coatings (cad, zinc, zinc alloys, Al) with chromate post treatment
- Chromated wash primer *DOD-P-15328*
- Direct to metal (waiver process)
 - State of art/best practice: PPG processes including Kleenihib 486 (*Chemkleen 340*) and Cheminhib 420 for OEM Stryker production in London, ON

- Example- Stryker:
 - Pretreatment / conversion coatings omitted
 - Primers applied direct to metal followed by topcoat
- Rationale:
 - Hex Chrome pretreatments prohibited for new ground vehicles
 - Viable alternatives have not been fully field tested



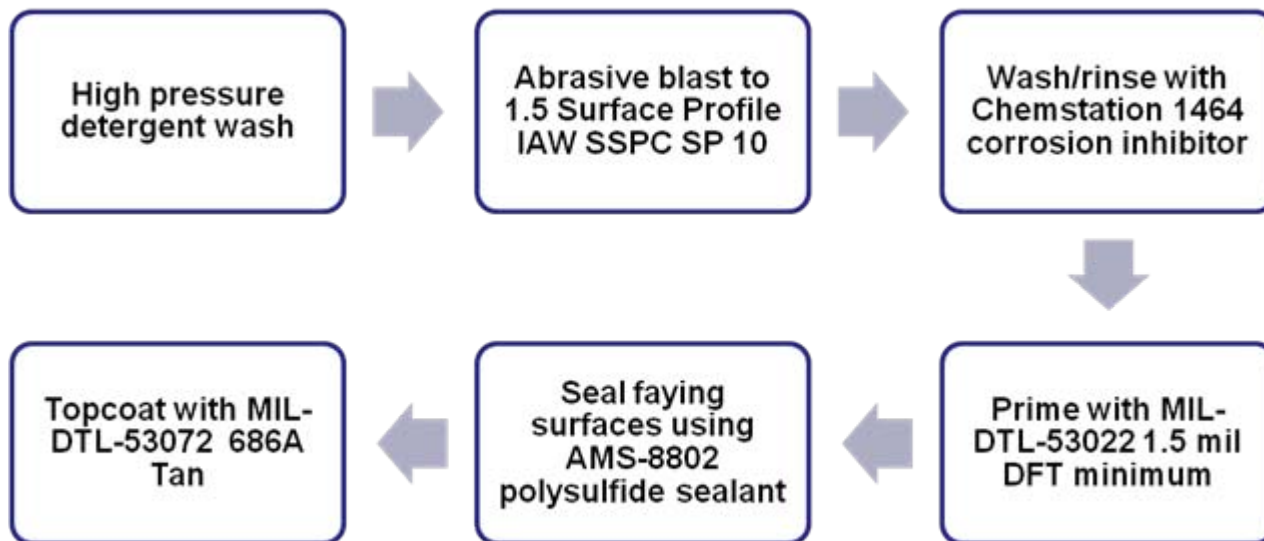
Stryker Armored Vehicle

GENERAL DYNAMICS
Land Systems



Current DTM Process Line at GDLS, London, ON

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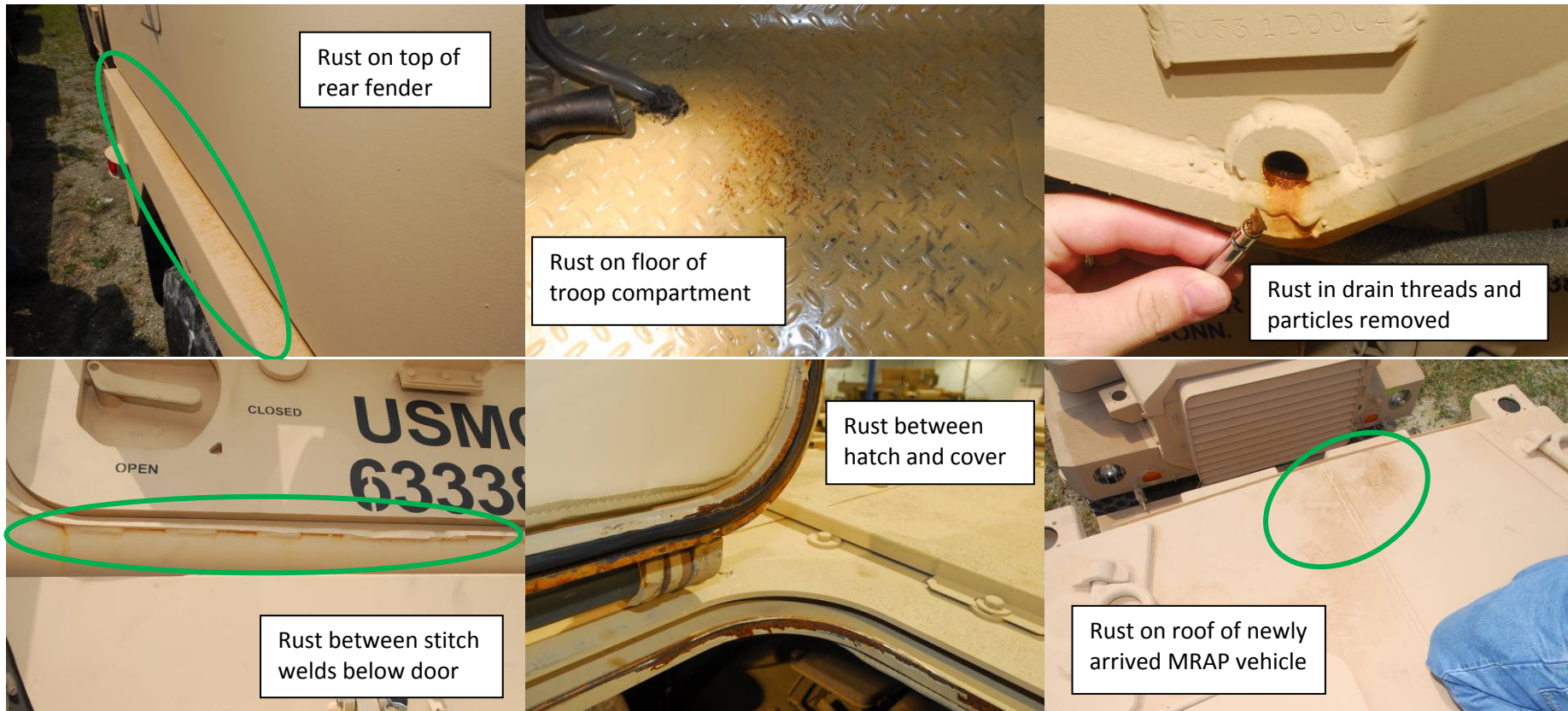


RG-33 MRAP

Process robustness is diligence dependent:

1. Type of media
2. SP 10? 6? 7? Degrades to? before applying inhibitor and painting
3. The true dry film thickness (DFT)?
4. Is it sealed properly?

- Corrosion Observed at SPAWAR
- Similar levels of corrosion observed on the systems available for review at SPAWAR (*system ages range from 0 to 56 days*)



U.S. Marine Corps, Corrosion Prevention and Control (CPAC) Program Support to MRAP II Acquisition

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MRAP (FPI variant) less than 18 months old showing extensive corrosion in certain areas

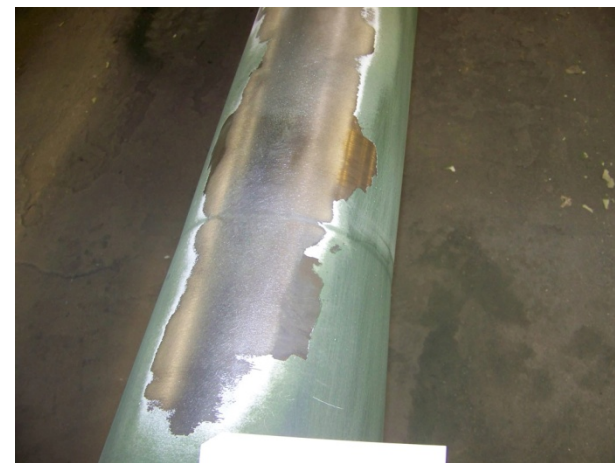


U.S. Marine Corps, Corrosion Prevention and Control (CPAC) Program Support to MRAP II Acquisition: John Repp, Andrew Sheetz

- *DTM process robustness is low*
- Concerns with hydrogen embrittlement in High-hard armor for Phos and Zn
- Inducing stress risers on outer surfaces of gun barrels
- Abrasive blasting can be time and cost prohibitive



Adhesion Problems on Steel FCS NLOS Muzzle Brake Barrel



Adhesion & Corrosion on LW Howitzer

Earlier NAVAIR Results

- Grit Blast + TCP
 - Allows for extended time between blasting and paint application without flash rust.
 - Slight adhesion benefit
 - No degradation to painted corrosion performance, need further optimization to determine corrosion benefit.



4130 w/TCP
168 hrs B117

Phase I:

- Obtain steel test samples, and select pretreatments and baselines.
- Survey the corrosion on existing high hard steel armored systems scheduled for reset.

Phase II:

- Assess coating systems through accelerated corrosion, adhesion, and rising step load tests
- Downselect to most viable candidate processes for Demonstration / Validation

Phase III:

- Dem/Val with rapid technology transition of the most viable candidate(s) to affected PMs,
- Revise MIL SPECS and TMs as needed.

Commercially available Alternative Technologies

- Select those that meet minimum requirements of TT-C-490
- Compare head-to-head against hex-chrome baseline to determine ultimate performance

Steel Pretreatments

- Non chromium – Henkel NT-1
- *Trivalent chromium – Surtec 650 TCP*
- Non-chromium – Chemetall Oxilan
- Non-chromium – PPG Zircobond 4200



Phosphate Sealers

- Non chromium - PPG Chemseal 100
- *Non-chromium - Surtec 580 (CFP)*



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Lab Validation on both High Hard and Low Carbon Steels

Corrosion Tests:

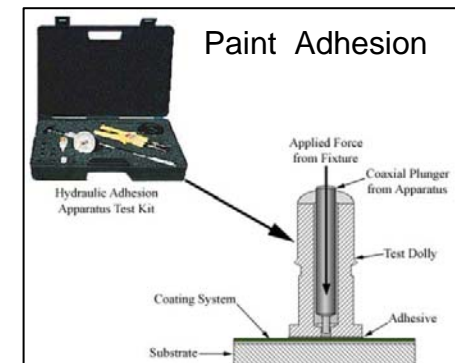
- GM9540P
- Humidity
- Outdoor Exposure (Cape Canaveral)



Accelerated Corrosion Chamber

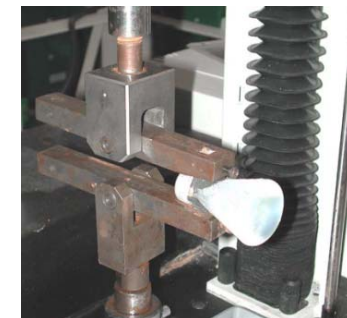
Adhesion Test:

- Pull Off Adhesion – ASTM D 4541
- Wet Adhesion – ASTM D 3359A



Stress Corrosion Cracking

- Rising Step Load – ASTM F 1624-95
- Notched Round Bar



Rising Step Load



Low Carbon Steel Matrix



Matrix using Standard Low Carbon Steel Panels for Corrosion and Adhesion Tests															
		Baseline					Alternative Coatings					Zinc Phosphate Sealers			
		Abrasive Blast	PPG Cheminhib 420	MIL-P-15328 (Wash Primer)	Gardolbond 24S w/ Chromate Seal FH-3	Gardolbond 24T w/ Chromate Seal FH-3	SurTec 650 (TCP)	Henkel NT-1	Chemetal Oxsilan	Chemstation 8354	PPG Zircobond 4200	Gardolbond 24S Spray		Gardolbond 24T Immersion	
												SurTec 580	PPG Chemseal 100	SurTec 580	PPG Chemseal 100
MIL-C-53022 / MIL-PRF-53039	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
MIL-C-53030 / MIL-PRF-53039	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Low-VOC MIL-C-53022 / MIL-PRF-53039	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Low-VOC MIL-C-53030 / MIL-PRF-53039	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Non-Chrome MIL-PRF-23377 / MIL-PRF-85285	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		65	65	65	65	65	65	65	65	65	65	65	65	65	65



High Hard Armor Steel Matrix



		Baseline					Alternatives					Phosphate Sealers			
												Gardolbond 24S Spray		Gardobond 24T Immersion	
		Abrasive Blast	PPG Cheminhib 420	MIL-P-15328 (Chromated Wash Primer)	Gardolbond 24S w/ Chromate Seal FH-3	Gardolbond 24T w/ Chromate Seal FH-3	SurTec 650 (TCP)	Henkel NT-1	Chemetall Oxsilan	PPG Zircobond 4200	Chemstation 8354	SurTec 580	PPG Chemseal 100	SurTec 580	PPG Chemseal
MIL-C-53022 / MIL-PRF-53039	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
MIL-C-53030 / MIL-PRF-53039	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Low-VOC MIL-C-53022 / MIL-PRF-53039	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Low-VOC MIL-C-53030 / MIL-PRF-53039	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Non-Chrome MIL-PRF-23377 / MIL-PRF-85285	Accelerated Corrosion	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Humidity*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Outdoor Exposure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Wet Adhesion*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pull-off Adhesion	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		65	65	65	65	65	65	65	65	65	65	65	65	65	65

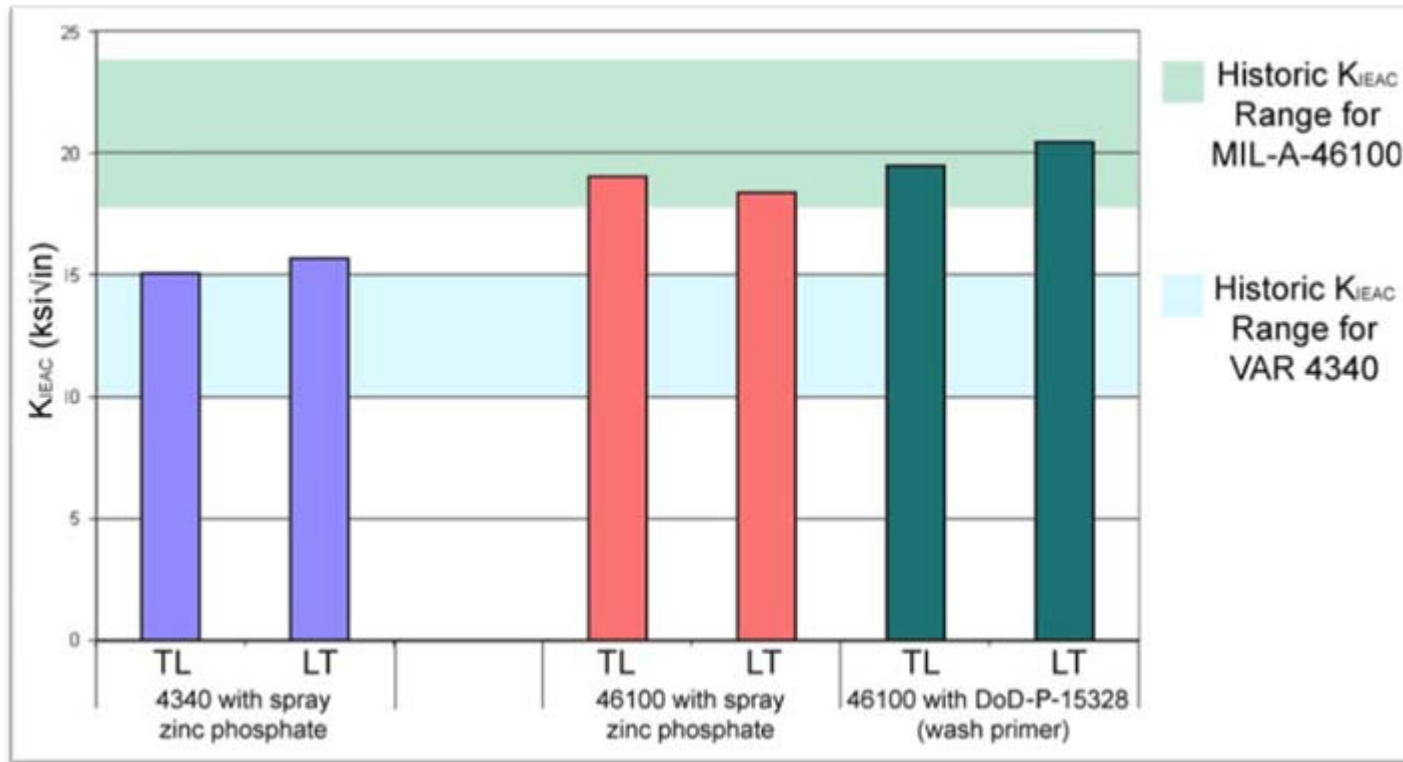
Total Panels 910

Rising Step Load Test Matrix for Evaluating SCC of High Hard Armor Steel															
Coatings	Tests	Baseline					Alternative Coatings					Phosphate Sealers			
												Gardolbond 24S Spray		Gardolbond 24T Immersion	
		Bare	PPG Cheminhib 420	MIL-P-15328 (Chromated Wash Primer)	Gardolbond 24S w/ Chromate Seal FH-3	Gardolbond 24T w/ Chromate Seal FH-3	SurTec 650 (TCP)	Henkel NT-1	Chemetall Oxsilan	Chemstation 8354	PPG Zircobond	SurTec 580	PPG Chemseal 100	SurTec 580	PPG Chemseal 100
Unpainted	RSL	5	5	5	5	5	5	5	5	5	5	5	5	5	5

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Concerns with Hydrogen Embrittlement



Phosphate according to Specifications MIL-DTL-16232G and TT-C-490.

- Use 120-240 hours ageing at room temperature

Proposed Dem/Val sites and Process Lines

- Army
 - Watervliet - phosphate seal and steel conversion coating
 - Letterkenny - phosphate seal
 - Anniston - phosphate seal and steel conversion coating
 - Corpus Christi - phosphate seal
- NAVAIR
 - Cherry Point - phosphate seal, TCP conversion
 - China Lake - Zn-Ni w/TCP, Phosphate seal, steel conversion coating
 - North Island – Class N primer dem/val underway, Phos Sealers
 - Solomons/Lakehurst: Steel conversion coating, Class N Primer



Proposed Dem/Val Platforms

- OEM Platforms
 - **Stryker**
 - **MRAP**
 - Joint Light Tactical Vehicle
 - Future Combat Systems



Stryker Armored Vehicle



FCS NLOS Cannon

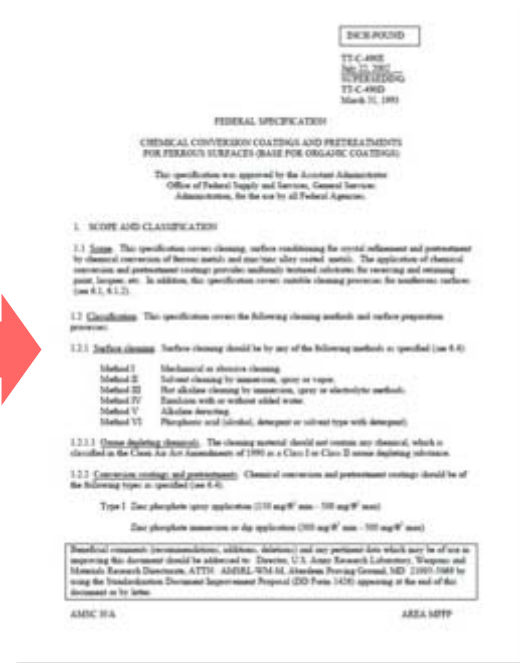
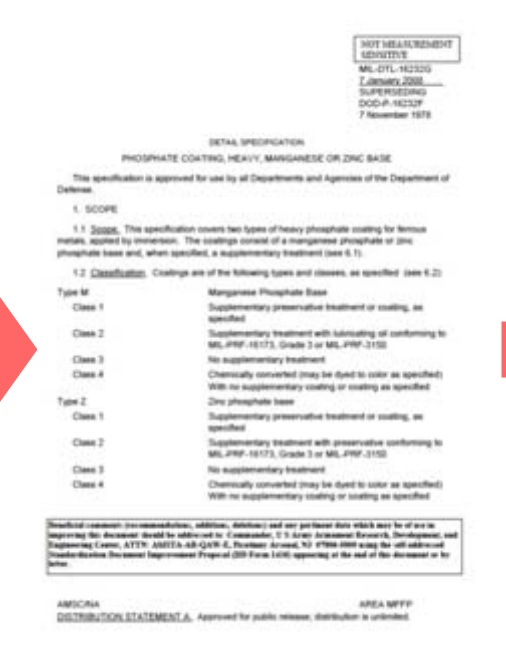


JLTV Family



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- Revise TT-C-490 (ARL cognizance)
 - Phosphate: revise TT-C-490 and MIL-DTL-16232G to create new rinse classes
 - Steel conversion coating: revise TT-C-490 to create new type



Current Phosphating Controlling Documents

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Questions

Back up Slides



Combined Project Milestones



Project Milestones																	
Title: Non-chromate, Zero-VOC Coatings for Steel Substrates on Army and Navy Aircraft and Ground Vehicles																	
Activities	Performing Org.	FY09				FY10				FY11				FY12			
		1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Obtain Laboratory test Armor Plate	ARL	█															
Initial Kick-off. Identify Dem/Val sites	All			█													
Survey of Current MRAP Corrosion	ARL & TARDEC			█													
Test Material Processed	NAVAIR			█													
Obtain & finalize Lab Validation	ARL & NAVAIR			◀────────────────▶													
Downselect to Best Processes	All						█										
Annual IPT Meeting	All						█										
Identify & Coordinate Field Sites	All						█										
Draft & Finalize Dem/Val Plan	ARL & NAVAIR						█										
Install Dem/Val Process Lines at Facilities	Depots						█			█							
Tracking & Monitoring of Vehicles/systems	ARL & NAVAIR						█			█				█			
Annual IPT Meeting	All									█							
Assess Results & adjust as Necessary	All									█				█			
Annual IPT Meeting	All													█			
Draft & Final ESTCP Report	ARL & NAVAIR															█	
Update MIL Specifications	ARL & NAVAIR															█	
Draft & Final Cost and Performance Report	ARL & NAVAIR															█	



Project Performers



Name	Organization	Contribution
Brian Placzankis – PI Jack Kelley	ARL; Aberdeen, MD	Principal Investigator. Lead coating evaluations and specification testing. Primary POCs for demonstration efforts.
Bill C. Nickerson – PI Amy Fowler	NAVAIR Materials Engineering Pax River, MD	Principal Investigator. Lead coating evaluations and specification testing. Primary POCs for demonstration efforts.
Steve Carr	Corpus Christi Army Depot Corpus Christi, TX	Depot lead for Army aviation depot demonstrations
Dennis Reed	Letterkenny Army Depot	Depot lead for phosphate sealer demonstrations
John A. Escarsega	DoD CARC Commodity Manager	Organic Coatings
James Mehring	FRC Cherry Point Cherry Point, NC	Depot lead for NAVAIR phosphate sealing
Dave Piatkowski	NAVAIR Materials/Support Equipment Lakehurst, NJ	Lead for support equipment demonstrations on steel and aluminum
Patricia Dodson	Anniston Army Depot Anniston AL	Environmental Engineer for Division of Production Engineering
Rick Sturdevant	PMO-MRAP Stafford VA	Corrosion engineer. Develop performance requirements for MRAP
John Cannon	Benet Laboratories, Watervliet Arsenal	Lead for steel conversion coatings on 4340 Howitzer barrels
Megan Boronowski	China Lake	Lead for Zn-Ni with TCP, Phosphate on Steel, Direct steel conversion coating for touch-up applications on Weapons platforms
Luc Doan	North Island	Lead for Non-chrome primer demonstrations on E2C2 aircraft outer mould line.

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